Antennas go to the head of the class at INL

Contributed by Regina Nuzzo

Wireless hotspots are cropping up nearly everywhere these days. Coffee houses and college campuses, large office buildings and living rooms - even entire towns are being rigged with access points that blanket an area with wireless Internet access.

James Hanneman, Hope Forsmann and Lynda Brighton (left to right) are working with colleagues Nancy Johnson, Allen Anderson and John Svoboda to develop a "smart antenna" system.

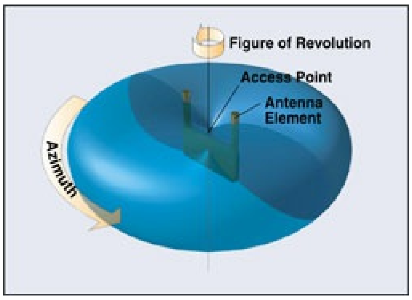
But covering large swaths of land with network access isn't always efficient or even desirable. Instead of using one large umbrella over an entire area, designers may prefer an access point that can hand out the equivalent of personal raincoats, giving network coverage that follows individual users - while leaving hackers unprotected and out in the storm.

For that kind of flexible coverage, antennas that send out network signals from access points need to be brainier than their average cousins. INL engineer Lynda Brighton and her colleagues Hope Forsmann, Allen Anderson, Nancy Johnson, John Svoboda and James Hanneman are working on ways to combine several antenna elements into one sophisticated "smart antenna" system. This will help wireless local area networks (WLAN) reach farther, juggle more users, navigate tricky environments, avoid electronic interference, and protect against rogue users.

Ultimately, the INL engineers hope to give WLAN users a more cost-efficient bang for their buck. "For wireless networks today," Brighton says, "it's crucial that solutions are affordable." WLAN access points will need to work in increasingly demanding environments, she says. And right now, designers are bumping up against some simple geometry problems. Simple problems, perhaps, but ones with intricate solutions.

Traditional WLAN Antennas: One Umbrella

Wireless Internet networks work on the same principles as cordless phones. A roaming laptop and a fixed access point - plugged into the Internet through a cable modem or DSL - communicate with each other through embedded antennas and exchange information over certain radio frequencies.



Traditional Antenna: The beam from a single antenna elements extends omni-directionally in a doughnut shape.

Typical access points use omni-directional antennas, which transmit and receive signals all around it, Brighton says. "Its coverage is shaped like a doughnut. It's equal in all directions along the horizon and then gradually decreases as you look up or down, with a small hole in the middle where the antenna itself is." In ideal situations, omni-directional antennas can handle the job well. But in the real world, umbrella coverage has its limitations.

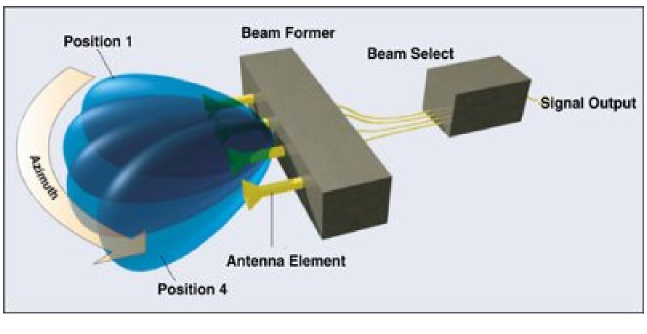
One problem is that the traditional doughnut shape can be a waste of energy, Brighton says. A large umbrella will cover every user within a fixed area and none beyond. So wireless networks can't selectively exclude some users near the antenna or extend coverage to others slightly farther away. And since WLANs use radio frequencies shared by other electronics - such as cordless phones, microwaves ovens, and other WLANs - an access point may run into interference from other equipment, Brighton says.

Also, standard antennas work best when there's a clear line of sight between the access point and users, Brighton says. But objects such as walls or furniture typically clutter WLAN environments and bounce signals around. The antenna indiscriminately picks up all signals within range, both direct and reflected. Called the multipath problem by antenna engineers, this can mean fluctuating service for connected users.

Finally, traditional access points face limited bandwidth because a typical access point uses only one frequency channel. A single laptop can exchange information with the access point at the fastest possible rate. Add an extra user with the same load, though, and "it's like the data pipe is now split in half," Brighton explains. Each user can work at only half the maximum speed. As the number of users climbs, bandwidth drops proportionally, and even high-speed connections can easily slow to a crawl.

Smart Improvements in Smaller Packages

But a so-called smart antenna system can circumvent many of these problems. It features a choreographed array of antenna elements that focuses its energy on a smaller, grape-shaped area instead of the traditional wide doughnut. Smart systems take advantage of a central processor to monitor users, control the beams, and customize the coverage area. And the smarter the antenna, the more customized the shape.



Processors in simple smart systems can switch among several fixed antenna beam directions to find the clearest signal from a laptop. Slightly more advanced smart antennas can steer beams across an arc to hone in on a user.

And best yet are adaptive systems, which continually mix information from a large array of antenna elements to give a highly customized, amoeba-shaped coverage area - extending range in some directions, blocking out narrow slivers of area in others, all while sorting through shifting multipath signals.

Smart Antenna: A digital signal processor and a beamformer algorithm are used to create simultaneous beams from antenna elements and point them in a variety of directions.

Mixed Signals, More Adaptability

The newest WLAN antenna technology has been made possible only recently with advances in other fields - namely, cheaper and smaller processors. Brighton's group tested two new, just-on-the-market smart antenna systems and a traditional omni-directional one, comparing a variety of performance measures.

They're putting these lessons to use by designing an even smarter, adaptive antenna system. Though still only in the design phase, Brighton says, the system will feature several antenna elements with individual transreceivers that feed into and from a sophisticated digital signal processors. Each independent processor algorithm will determine how to best tweak each antenna element to optimize energy in one direction while minimizing energy in all others. This, she explains, will minimize effects of interference and multipath while also increasing range and blocking unwanted users. And since independent digital beams are formed, each user will get virtually no drop in bandwidth, no matter how many users are connected - though limited, of course, by processor and Internet connectivity capabilities. What's more, she says, a technique called Doppler shift removal will let the system track and adapt to moving users in real time.

The trick, Brighton says, is designing the adaptive antenna system to be affordable, which means using existing transreceiver and digital signal processor technologies. "The hardware is an integral part of the system, but we don't want to mess with that part. Whether we can build something with off-the-shelf components - that is a real challenge."

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